INTERIM REPORT

SOURCES OF
TEST DATA BASE INFORMATION
FOR
A NATURAL RESOURCES INFORMATION SYSTEM

July 1975

DEPARTMENT OF NATURAL RESOURCES
Division of Research & Technical Information
Geological Survey
P.O. Box 250, Rolla, MO 65401

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EXECUTIVE SUMMARY

The first images beamed back to earth from the Earth Resources Technology Satellite (ERTS-1) brought home the realization that enormous amounts of information are being gathered today that were not available only a few years ago. In fact, the information is being accumulated faster than existing data systems can handle it.

Agencies using natural resources information realized that the vast quantities of data needed to be assimilated in a manner that would permit rapid manipulation and retrieval in a usable form. To solve the problem in Missouri, the Governor set up an Advisory Committee on Technical Data Sharing with the idea that State agencies should share their technical information and expertise. The Committee's initial concern was to coordinate the acquisition and use of satellite imagery, aerial photography, and other remotely sensed data. The Committee completed studies in May of 1974 and made three important recommendations:

a. That an Interagency Council for Natural Resources Information be established,

b. That a Natural Resources Data System be developed, and

c. That a Cartographic and Remote Sensing Center be established.

The Natural Resources Information Council was considered a necessity because several departments in State government rely on the same natural resources information. Council representatives were selected from the Office of Administration; Department of Agriculture; Department of Conservation; Department of Consumer Affairs, Regulations & Licensing; Department of Higher Education; Department of Highways; Department of Natural Resources; and Department of Public Safety.

To develop a Natural Resources Data System that could be used by all interested State agencies, the Governor's Committee recommended that a "Pilot Study Area" approach be used to test the kinds of data needed. In other words, data were to be collected in two specific locations, or "Pilot Areas", and studied to determine the feasibility and requirements of using one system of data management for several agencies with diversified needs. Since Electronic Data Processing System design, encoding, programming and computer costs are extremely high, it was considered important that Pilot Areas be representative of the state as a whole.

Two Pilot Areas were selected on this basis and because of their wide appeal to the various State agencies involved. One of the areas, the Lake of the Ozarks, was cited as a "critical area" in the Department of Community Affairs' study, AREAS SENSITIVE TO DEVELOPMENT IN MISSOURI – PART III: PHYSICAL CHARACTERISTICS AND CONSTRAINTS FOR DEVELOPMENT (1973). This same area of the state was also cited in the Missouri Geological Survey's report, PHYSICAL CONSTRAINTS TO URBAN DEVELOPMENT IN NINETEEN SELECTED AREAS IN MISSOURI (1974) as one of those most environmentally sensitive to development. The Lake of the Ozarks area becomes the second largest city in Missouri during the peak of the vacation season, but it does not possess the normal sanitation services necessary for a city of that size.

The second Pilot Area selected was the Thomas Hill Reservoir area in the Little Chariton watershed in northcentral Missouri. Although it was not judged to be as sensitive as the Lake of the Ozarks area in the 1974 report, this area was chosen because of its wide appeal to natural resources-related agencies involved.

In addition to serving as a "testing ground" for accumulation of data for a Natural Resources Data System, the Pilot Areas are to serve as test sites in evaluating remote sensing and its applications in acquiring data. The study will demonstrate the cost-benefit ratio of using remotely sensed data as opposed to conventional field methods as well as provide an evaluation of other data sharing methods. Goals are to coordinate and standerdize data acquisition and mapping procedures.

This report is an initial step in the development of test data sets from these two Pilot Areas for a Natural Resources Data System for Missouri. The report is restricted to an inventory of remotely sensed data and an evaluation of geologic and hydrologic data that are available for the Pilot Areas. Additional data are needed for the test phase of System development. Recommendations (if funding is available) are to:

a. Explore the possibilities for the acquisition and application of additional remotely sensed data for the two areas.
b. Have 1/62,500 base maps made for some areas.
c. Make geologic structure, bedrock, surficial materials, and engineering geologic maps for the two areas.
d. Evaluate the water resources of the two areas.
e. Obtain additional information about mineral resources.

In addition to geologic information, data should be compiled and evaluated on forests and wildlife. Agricultural data are needed, as well as an inventory of land use and information on the population and economics.

Additional funding is required to develop and support a Natural Resources Data System for Missouri. Expansion of the System should be a continuing process, although funding and personnel commitments are too uncertain at this point to establish clearly defined time frames for development of an operational system. The assistance provided under the Urban Planning Grant Project has been extremely beneficial during the first year of this program, and provision for similar support in the future is essential.

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FOREWORD

The pilot study approach was conceived by the Governor's Advisory Committee on Technical Data Sharing and carried on by the Inter-Departmental Council for Natural Resources Information. Funding was through a contract between the Office of Administration and the Geological Survey, Department of Natural Resources.

The following history and activities of the committee and the council were taken from an information pamphlet recently published by the Natural Resources Information Council.

> "Governor Christopher S. Bond appointed an Advisory Committee on Technical Data Sharing late in 1973 and charged it with 'seeking to improve coordination of, and utilization of certain technical data having application in the natural resources field'.
>
> "The Committee's initial concern was to coordinate the acquisition and use of satellite imagery, aerial photography and other remotely sensed data. The Governor wanted state agencies to share their technical data and expertise. To do this, an Electronic Data Processing system to store and retrieve information quickly was deemed essential.
>
> "...Working rapidly the Advisory Committee completed its studies and, in May, 1974, made recommendations to:
> * Establish a Council for Natural Resources Information
> * Develop a Natural Resources Data System
> * Set up a Remote Sensing Center
>
> The Governor directed James L. Wilson, Director of the Department of Natural Resources, to proceed with the formation of the required council structure. On October 9, 1974, the Inter-Departmental Council for Natural Resources Information met for the first time.
>
> "Because natural resources information is essential to the activities of so many departments, representatives from several were named to serve on the Council. They include:
> Office of Administration
> Department of Agriculture
> Department of Conservation
> Department of Consumer Affairs, Regulations & Licensing
> Department of Higher Education
> Department of Highways
> Department of Natural Resources
> Department of Public Safety
>
> "The key to Missouri's energy and resource management problems may be its ability to "harness" the maze of information generated by research, remote sensing and other modern techniques. The problem facing the Council is how to develop and coordinate the use of this unbelievable amount of information. Consequently, the following projects are receiving top priority:

"Natural Resources Data System:

To establish an information system that will be useful to all state departments and the public as well, the Council must know what data are used, who needs it, and where it can be found. Thus, an in-depth inventory of data categories and needs (by Agency) is in progress and should be completed by summer, 1975.

The Division of EDP Coordination, Office of Administration, is coordinating programs that can be computerized. An interim "Index to Data Sources" is being produced along with recommendations for basic system needs and design plus estimated costs and an analysis of needs and anticipated benefits.

"Topographic and other Special Mapping Programs:

Maps are essential in planning and development, whether it be highways, subdivisions, mining operations, recreation facilities or other needs. Many times, the same modern maps are needed by several agencies and there are duplicate costs and effort because these needs are not known. The Council is working to coordinate needs and to establish priorities for topographic, orthophotoquadrangle and related mapping programs.

"Remote Sensing Center:

Remote sensing (observing and recording information from a distance, without contact) and other space technology offer enormous potential for applications in Missouri. These include such things as an inventory of land use, hydrology, surficial geology and regional geologic structural analysis, as well as many others.

"Emphasis by the Council thus far has been in keeping abreast with development and maintaining rapport with Federal agencies involved in remote sensing work. Now, attention is being directed to the following projects:

* A Remote Sensing Data File at the Geological Survey in Rolla is being further improved and developed.
* Information and technical assistance are being provided to State agencies and others interested in using remotely sensed data.
* Conferences and workshops on benefits and uses of remote sensing in Missouri are being provided with the assistance of the University of Missouri.
* An "Index to Photographic and Remotely Sensed Data in Missouri" is being prepared under the direction of Dr. Chris Johannsen, MU Extension, and funded by Rural Development. All departments are furnishing information for compilation of these data.

"In summary, the Inter-Departmental Council for Natural Resources Information is coordinating acquisition of natural resources data, making it available to everyone, and providing the technical expertise for its most beneficial use. Its goals include:

* A Natural Resources Data System that can best meet State agency and institutional needs in providing services to Missourians.
* A Remote Sensing Center that will coordinate acquisition and storage of remotely sensed information and provide needed technical assistance for its use.
* Coordination and development of multi-discipline grant proposals that will provide for natural resources data needs without duplication of effort.
* Preparation of special reports on EDP and remote sensing applications that will provide needed natural resources information for use by many agencies.
* Coordination of requirements and priorities for topographic and other special mapping programs.
* Make adequate natural resources information available for routine needs of State and governmental agencies as well as for natural resources policy requirements.
* Provision of liaison between State agencies and Federal agencies involved in comparable projects at the national level.

MEMBERS OF COUNCIL

"Office of Administration
Steve Boody (Planning and Analysis)

Department of Agriculture
John Sanders

Department of Conservation
Joe Bachant (Planning Section)

Department of Consumer Affairs, Regulations and Licensing
Earl Cannon (Director of Research, CID)

Department of Higher Education
Keith Smallwood (Commission on Higher Education)
* David Barr (University of Missouri-Rolla)
* Chris Johannsen

Department of Highways
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* Luther Skelton (Division of Planning and Policy Development)
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Department of Public Safety
Charles M. Kiefner (The Adjutant General)"

* Associate Member

The most important Council project, the establishment of a Natural Resources Data System, is the primary concern of this report. The need to assimilate vast quantities of natural resources data in a system that would allow rapid manipulation and retrieval is paramount. Other states are finding that natural resources data systems are essential in meeting Federal, State and general public demands. Examples are EPA pollution control monitoring requirements, environmental impact statements, and natural resources management programs.

A major cost of such a system is the encoding (or converting) of the data base into a form that can readily be electronically processed. Because decisions must be made as to what data to include in such a system prior to commencing the design phase, a state-wide inventory is being made of agency and institutional data needs and sources. An essential element in the design and development of a data system for state-wide application is a provision for thorough testing of a suitable sample data base. Some states, such as New York and Oregon, have approached the problem of testing through the development of a "pilot project area" concept. This allows the design parameters of the data system to be tested and modified with a minimum cost for encoding because of the relatively small sample set of data involved. It was important that the pilot area be carefully selected so that it would include samples of all kinds of natural resources information and representative of the state as a whole.

The following discussion represents a preliminary stage in such a pilot study concept.

I. INTRODUCTION

The purpose of the pilot area approach is to provide a test data base so the design parameters of the developing Natural Resources Data System can be evaluated. Ideally, a broad range of data input should be available; the data

should be as complete as available time, funds and current data allow. During this stage, principal emphasis has been placed on planning and developing a satisfactory data base. Preliminary effort has been directed toward an inventory and evaluation of the information available on geology, water resources, and mineral resources, as well as the evaluation of available base maps and remote sensing data.

The results of such a program should produce other benefits as well. The cost-benefit ratio of using remotely sensed data as opposed to conventional data acquisition methods will be demonstrated. The test phase will also provide a basis for the evaluation of data sharing methods on a state-wide as well as Federal basis. It is further hoped that data acquisition and mapping procedures will be standardized. The end result of this phase is the inventory and evaluation of existing geologic data and recommendations of additional data necessary to insure that the data base is adequate for testing the Natural Resources Data System.

Depending on the availability of funds for development of the system, the data base that is assembled for the pilot areas may or may not be utilized as soon as it is completed. It may be shelved temporarily until system design can be accomplished.

Publication (in the traditional sense) of material gathered for the pilot areas input will not be practical except in instances where special topical studies made in support of the program have other specific objectives. Ultimately, a formal report should be published on the project as a test program utilizing a complex data base and emphasizing the potential for an integrated analysis of factors. This step would necessarily follow the test phase and would serve as its documentation.

II. SELECTION OF STUDY SITES

Two study areas (pilot areas) were selected on the basis of their complex geologic interrelationships. There are related groundwater problems such as pollution, losing streams, etc., that need to be defined. The nature of the bedrock geology and surficial materials that are causing these problems is not definitely known. Coupled with this is the problem of the co-existence of mineral extraction, recreation facilities, and power production in a relatively small area.

The Lake of the Ozarks area (fig. 1) is a complex study site since information can be obtained on an existing reservoir system as well as on a developing urban-rural area. Documentation of baseline data is needed. The Lake of the Ozarks was cited as a "critical area" by the "Areas Sensitive to Development in Missouri Part III: Physical Characteristics and Constraints for Development (1973) and as a "sensitive area" by the "Physical Constraints to Urban Development in Nineteen Selected Areas in Missouri" (1974). Within the time frame and money provided in this contract, it was impossible to approach a complete study of the Lake of the Ozarks area. Instead,it was decided to select a representative major basin in the Lake of the Ozarks area, preferably one with development in the early stages. The site selected for study include the Niangua and Grandglaize, paired watersheds that comprise an area of 1,200 square miles extending south from the lake.

The Thomas Hill Reservoir area (fig. 1) almost entirely within the Little Chariton watershed, comprises 795 square miles. In the "Sensitive Areas" report, this area was not judged as critical as the Lake of the Ozarks. However, the area was selected for its wide appeal to all disciplines represented among agencies requiring natural resources information. The area exemplifies a rural-agricultural setting where there is a distinct possibility that strip mining of coal will be expanded.

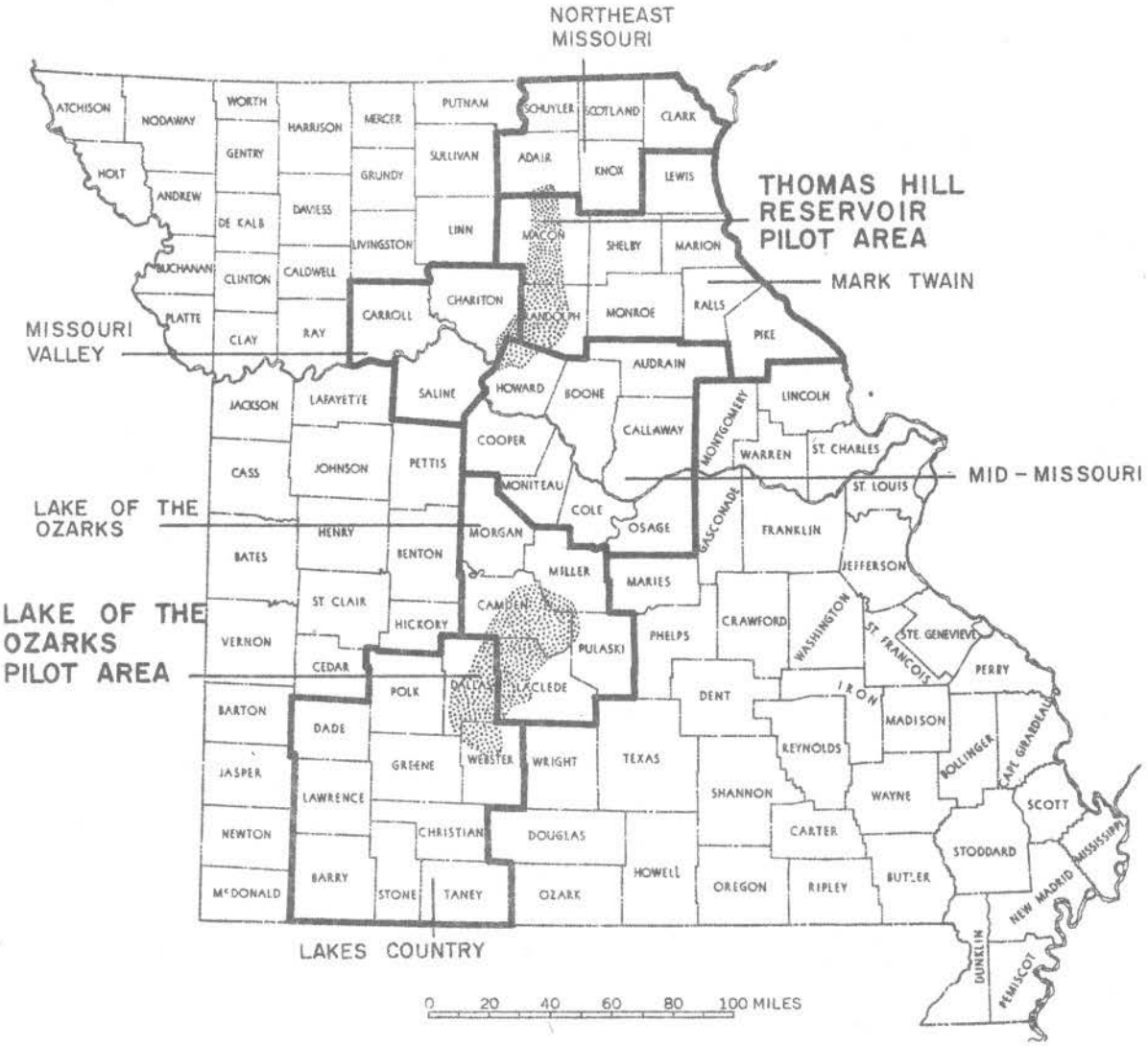

Figure 1

Pilot areas under study are the Lake of the Ozarks and the Thomas Hill Reservoir areas.

III. INDEX TO AVAILABLE REMOTELY SENSED AND PHOTOGRAPHIC DATA

To identify remote sensing applications, a comprehensive review was required of exsiting remotely sensed data available in the pilot areas. The University of Missouri Extension Division was able to obtain money through the State Rural Development Committee to produce a state-wide Remotely Sensed and Photographic Data Index. Much of the data for this index was extracted from the State Geological Survey files with the assistance of contract-funded personnel. The Index includes index maps showing Regional Planning Commission areas as well as tabulated data itemizing the air photos and other remotely sensed information available for each Planning Region in the state. Ordering information, along with all known public and private sources of data, is supplied. An outline of the Index to Remotely Sensed and Photographic Data is included in the appendix at the end of this report along with other relevent information.

This index meets project requirements as well as other needs so the time used in this cooperative effort was well spent. The product of this effort is scheduled for publication in late summer 1975.

IV. EVALUATION OF EXISTING BASE MAPS

Prior to commencing the geologic study of each area, it was necessary to determine the availability of accurate base maps of appropriate scales. Geologic data, by its nature, requires accurate geographical location, and topography plays an important part in the expression of rock formations in the field. Lists of available base maps for the two study areas appear in Tables 1 and 2.

New 7½-minute orthophotoquadrangle maps, being prepared by the U.S. Geological Survey to cover the Lebanon and Stoutland 15-minute quadrangle map areas,

are scheduled to be published in January 1976. The aerial photographs for these orthophotoquadrangles made during March 1975, are available at the Missouri Geological Survey in Rolla, Missouri. Both high altitude and low altitude photographs are on file. The 7½-minute quadrangles will have to be reduced to 1:62,500 scale for final compilation of geologic and other data.

TABLE 1
BASE MAPS AVAILABLE FOR
THE LAKE OF THE OZARKS AREA

Quadrangle Map Name	Scale	Approximate % of map in study area	Contour Interval	Year
Drynob	15'	35	20	1954
Fordland	15'	2	20	1939
Iberia	15'	20	20	1933
Lebanon**	15'	100	20	1941
Long Lane*	15'	100	20	1939
Macks Creek*	15'	75	20	1934
Manes	15'	5	20	1941
Niangua*	15'	30	20	1946
Richland	15'	45	20	1954
Stoutland	15'	85	20	1933
Strafford*	15'	15	20	1947
Buffalo*	7½'	50	10	1961
Camdenton	7½'	12	20	1959
Charity*	7½'	95	10	1961
Halfway*	7½'	25	10	1961
Mansfield NW*	7½'	2	20	1951
Toronto	7½'	55	20	1959
Tunas	7½'	3	10	1960

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* Unpublished geologic reconnaissance map is on file: field checking and possible revision are required for pilot study purposes.

** Published geologic map is available

TABLE 2
BASE MAPS AVAILABLE FOR
THE THOMAS HILL AREA

Quadrangle Map Name	Scale	Approximate % of map in study area	Contour Interval	Year
Kirksville*	15'	25	20	1938
Elmer	15'	50	20	1942
Atlanta	15'	5	20	1908
Lagonda	7½'	50	10	1953
Bevier South	7½'	100	10	1953
Macon	15'	20	20	1908
Jacksonville	7½'	25	10	1971
College Mound	7½'	100	10	1953
Prairie Hill	7½'	75	10	1953
Salisbury	7½'	60	10	1956
Clifton Hill	7½'	100	10	1953
Moberly	7½'	45	10	1953
Renick	7½'	5	10	1953
Higbee	7½'	50	10	1953
Armstrong	7½'	75	10	1953
Forest Green	7½'	80	10	1956
Cambridge	7½'	25	10	1956

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* Advance sheets may be available within the next year.

Available geologic Maps:
Geology of Bevier 15' quadrangle, Gordon,et.al., 1891
Geology of Huntsville 15' quadrangle, Marbut & Gordon
Geology of east half of Glascow 15' quadrangle; Marvin & Marvin, 1950

Numerous reconnaissance 7½' quadrangle maps prepared by Charles Robertson(Missouri Geological Survey) in conjunction with his coal resource studies
Detail not known at this time. Assumed to be about one quarter to one half that required for final map.

V. Geocoding Systems for Natural Resources Information

The mission of natural resources oriented agencies is to effectively manage the particular resources under their jurisdiction. The manager, whose decisions affect the utilization, development or preservation of these natural resources, makes these decisions based on analysis of facets of data. The availability and timeliness of these data are extremely important to the manager. It is not enough to have created large amounts of data, it is important to be able to accurately retrieve the data needed for particular decisions. Many in state government envision a Natural Resources Information System as being developed with the primary objective of providing quick access to the latest available data for use in making decisions.

The common denominator of all data to be placed in the Natural Resources Information System will be the geographic location since almost all data can be referenced in this manner. Because geographic location can provide a key for recalling many types of data about a particular area, it is essential that all data be identified by a geographic location. In some instances, it may be necessary to graphically display the location of data items on maps. These data maps will also require geographic locations of such nature that they can be produced in a mapping format. These geographic locations will usually be written in a form that can be electronically processed. This is called a "geocode" (a code for the geographic location, in other words). The geocode can take a number of forms. It may be a point location in x and y coordinate value. It may be an irregular polygon whose corner coordinate values are known - these polygons can be county boundaries, civil township boundaries, land parcel ownerships, or many other irregularly shaped parcels. In addition to points and polygons, it is possible to identify a regular square parcel of land (which is called a "cell"). A coordinate value is assigned to the center of the cell or some other

consistent point. These three methods: point coordinates, polygons defined by a series of coordinates, or a cell with a single coordinate are the three commonly used geocoding methods. The type of data and the system display requirements will determine which method of geocoding will be used for each kind of data. These decisions will be made based on the economics of data encoding and display requirements.

The information system developed for state level usage will include a geocoding system for the state operation. This system is essentially a "software" product. The geocoding system, which must allow for acceptance of data from any of the three geocoding methods, must also accept data coded in any one of the various coordinate systems available. Both of these tasks can be performed by an electronic computer without any difficulty as long as it is told what the parameters and possibilities are. The design of this system will require a great deal of time and effort, but will ultimately provide for uniform acceptance of the wide variety of data generated by State and Federal agencies.

It is essential to recognize that, in designing a data base, one of the basic criteria to be established is the geocoding procedure. This procedure must be designed hand in hand with the determination of the data elements and the system display requirements. At this point in the project, data elements and system display requirements have not been determined, and therefore it is impossible to define the geocoding method that will fit the data to be obtained from this pilot project. The Division of Research and Technical Information has gathered information on many of the geocoding methods in use today. This information will be utilized in determining the method or methods to be utilized in this pilot project. It is essential to note again that the overall

geocoding system must be designed so that it will accept any geocoding method based on one of the recognized coordinate systems. The design of this geocoding system should take place as an integral part of the overall Natural Resources Information System.

VI. INVENTORY AND EVALUATION OF THE EXISTING GEOLOGIC DATA BASE

INTRODUCTION

A broad range of natural resources information is gathered or developed and utilized by the State Geological Survey. The traditional and functional organization of that agency into sections, such as the Areal Geology and Stratigraphy Section, serves as the basic structure of this part of the report.

Within the State Geological Survey, geologic efforts are separated into several disciplines, and these disciplines can be broadly categorized into two main types, those that are primarily data producing, or basic in nature, and those that are primarily data using, or applied. Of the former, the discipline of Stratigraphy is "...that branch of geology which treats of the formation, composition, sequence, and correlation of the stratified rocks as parts of the earth's crust." (Dictionary of Geological Terms, 1962, p. 476.) It is a principal basic data-producing discipline within the Survey. The applied geologic disciplines of Water Resources, Mineral Resources and Engineering Geology not only utilize that basic data produced through stratigraphic activities and research, but they also generate specific data and statistics within the realm of their specialities.

STRATIGRAPHY

Data input available through and from the Geological Survey's Areal Geology and Subsurface Geology Sections is discussed below:

Bedrock Geology, involving the study of stratified consolidated (cemented,

or hard) rocks; Surficial Geology, dealing with unconsolidated (uncemented) stratified rocks, such as river or stream deposits (alluvium), glacial deposits (Pleistocene deposits), and residual weathering products of rocks (residuum); and Subsurface Geology, dealing with rocks not exposed on the surface but known and studied through samples taken while drilling water and oil wells. The principal forms of data produced are maps and written reports.

Bedrock Geology

Data produced through studies of bedrock geology are presented in published reports of research and on geologic maps. The former involve detailed descriptions of the various rock formations, and includes information such as composition, grain size, thickness, color, amount of chert (flint), etc., that are necessary for use in mineral resource studies (such as determining limestone resource possibilities). Geologic maps are practically a requirement for making an accurate analysis of engineering geologic conditions of an area. They depict the distribution and thickness of bedrock and this, coupled with surficial materials maps and slope information (from topographic maps), provides the basic data from which engineering geologic maps are produced. These, in turn, are necessary for making an accurate evaluation of potential land use.

At present, a bedrock geologic map exists for the whole state at a scale of 1/500,000 (McCracken, 1961). However, this scale is totally inapplicable for accuracy of much less than one mile, so the map gives only a very general idea of the rock formations present at any particular site. More detailed mapping (at a larger scale) is necessary to depict the conditions present at sites if these maps are to be useful to other disciplines of geology.

Through experience, the optimum scale for present requirements is 1/62,500 for such needs as engineering geology, groundwater geology, and mineral resources. Most of the available geologic mapping is at the "reconnaissance" level at

1/62,500 scale, developed for the Geologic Map of Missouri (1961), and is not detailed enough for the final 1/62,500-scale geologic map. Within the Lake of the Ozarks pilot area, only the Lebanon 15-minute quadrangle (Searight, 1955) has been published. It has been found to have errors and will require extensive field checking. Ninety percent or more of the two pilot areas need extensive investigation to attain the desired 1/62,500 level of detail. Such mapping is in progress in the Niangua Basin area as a part of another study. Any larger scale is, at this time, impossible to obtain for the entire area because of manpower and financial conditions. This includes most of the southern pilot area and thus will meet most of the need for suitable geologic mapping for that part of the project.

The following studies, which will require considerable additional data, are recommended as desirable at some future time:

a. More detailed geologic mapping in the Thomas Hill area.

b. Stratigraphic studies of rock formations in both areas.

c. Detailed structural investigations of both study areas.

Stratigraphic studies of selected individual rock formations should be made particularly of those formations of potential economic value or with particular engineering characteristics that are important on their own merit. Coal-bearing formations should be detailed in the northern area, as should limestone-bearing strata in both regions.

Structural information is necessary in studies of engineering geology, groundwater hydrology, and distribution of available mineral resource commodities. Some details of major structural elements should be mapped in the pilot regions; these could accompany geologic maps.

Surficial Geology

Surficial geology is concerned with the description of and distinction between surficial materials on or near the earth's surface. Usually unconsolidated (uncemented),

these materials are discussed under the general term surficial materials. They can be distinguished both by mode of origin and physical properties. Their characteristics are primary elements in preparing an engineering geologic map, the value of which will be discussed under "Engineering Geology".

Two forms of available data provide considerable basic information for the Survey's surficial materials mapping program. Existing soil maps of various counties in the study areas are a basic information source and where these are not available, data are taken from the State Soil Map of Missouri (1931). In a similar manner, published and unpublished bedrock geologic maps provide needed data on parent materials and physical properties of surficial materials at depth. Information provided by the Missouri State Highway Department is helpful in defining the properties of various surficial material units. Such data will be utilized in areas where investigations have been completed by the Missouri State Highway Department.

Available data on the mechanical properties of surficial materials also include unpublished theses completed at the University of Missouri in Columbia and Rolla. These studies include investigations of glacial till deposits and their mechanical properties. Work of this kind has been more extensive in the Thomas Hill Reservoir area than in the Lake of the Ozarks area. However, extensive Missouri Highway Department investigations have aided in the definition of mechanical properties and thickness of surficial material in the Niangua Basin.

Information acquired by various remote sensing techniques will be utilized in this study, particularly in delineating major surficial material types. This includes data interpretation from conventional photography and mapping acquired from aircraft and satellite systems.

It is recommended that, when time and resources are available, the following surficial deposits investigations be undertaken in the pilot areas. The area to be considered first for surficial materials mapping will be the Lebanon Quadrangle in the Niangua Basin. This has been chosen because a county soil survey map and a geologic map have already been published. Additional geologic mapping is also available in State Geological Survey files. Considerable data from previous engineering geology studies should be helpful, especially that from the investigations of Dry Auglaize Creek and Goodwin Hollow, where the hydrologic setting of these watersheds has been evaluated because of pollution problems around the City of Lebanon.

Mapping will be extended northward from the Lebanon area and the adjoining quadrangles. Basically, the mapping detail will be at a reconnaissance level.

The area selected for initial study of surficial materials in the Thomas Hill Reservoir area is in the vicinity of the Thomas Hill Reservoir. Available soils maps, engineering data on mechanical properties, and satellite-acquired photography provide a broad and useful data base. Once relationships of surficial materials have been defined in this representative area, data will be translated across the entire Chariton River watershed.

The scale of available topographic maps is 1/62,500. Although a larger scale, 1/24,000, would permit more definitive notation of surficial material unit boundaries, it exceeds the detail of information available as well as the scale needed for the final map. A smaller scale base, for example 1/250,000, would not be inadequate to show significant differences of surficial material units.

Subsurface Geology

The two previously discussed parts of Stratigraphy both primarily utilize data obtained from rock and materials present, or exposed, at the earth's surface. However, both bedrock and surficial materials are extensively studied through the

aid of samples collected during drilling of water wells or during oil and mineral test drilling. That aspect of geology that is primarily concerned with the description and collection of stratigraphic data from sources below the earth's surface is the discipline of Subsurface Geology.

Subsurface stratigraphic work, in conjunction with "surface" stratigraphic reports, provides the stratigraphic framework required for applied disciplines. Thus, the distinction between subsurface and "surface" stratigraphy is one of emphasis since the basic methods and results are compatible. Subsurface data are used where rocks are not exposed on the surface to obtain a more complete picture of the rocks in an entire area.

Sources of subsurface stratigraphic data available at the State Geological Survey include:

a. Well logs - graphic insoluble-residue logs (made by professional geologists).

b. Drillers' logs - made from notes in log books provided by well drillers.

c. Written well logs - "top" logs (data in typewritten form taken from well logs).

d. Mechanical logs - limited number of electric, gamma ray, sonic and other logs (geophysical logs).

e. Card files - statistics on all active and abandoned oil and gas wells since 1860.

f. Literature - published, unpublished, and in preparation.

g. Samples - drill cuttings and rock core.

The subsurface data available for the Thomas Hill area are not as complete as that available for the Lake of the Ozarks area. Most of the available data in the Thomas Hill area is in the form of water well logs. Potable ground water is available only from glacial and alluvial deposits so that very little drilling into bedrock formations occurs in the Thomas Hill area. Therefore, deep subsurface data are not as abundant.

In recommending future subsurface activities, dependent upon funding, every effort

should be made to develop existing data and to acquire additional information such as coal prospect drilling, as it becomes available in the Thomas Hill area. There appears to be sufficient data already available for shallow subsurface studies pertaining to the glacial cover.

Using available data in conjunction with bedrock geologic mapping, structural maps depicting areas of faulting and folding should be produced. These would aid in determining criteria for the distribution of mineral resources and the movements of ground water.

WATER RESOURCES

Lake of the Ozarks Area

Ground water in the study area is important as a source for almost all water supplies, both rural and urban. This is one of the more sensitive areas of the state from a water resource point of view, because of surfacewater and groundwater interchanges. These interchanges are of particular interest in developing and controlling use of land. The streams, which lose all or most of their flow shortly after a rain, could provide ready access for pollutants into the groundwater reservoir. This complex interrelationship should be understood in the study area so that a plan can be formulated for the wise management of sewage and other waste materials.

The Missouri Geological Survey, Department of Natural Resources, and the U.S. Geological Survey are beginning work on a 3-year cooperative basin study in an area that coincides, for the most part, with the Lake of the Ozarks area. The information to be gained from this cooperative program corresponds closely with data required, and it is anticipated that the basin study can meet pilot study requirements for development of a test data set on water resources.

The following sections on approach and objectives (taken from the workplan developed for the cooperative basin study) illustrate the kind of information

at will be provided by that study:

"1. At present, there are approximately 350 wells in the study area for which the Geological Survey has records. This includes depth, formations penetrated, water levels at the time the well was drilled, elevation of the well at land surface, and in some instances, yields in gallons per minute. These records will form the basis for the gathering of additional data in the area. It will be necessary to visit all of these wells to determine present water levels so that a water level map (potentiometric map) can be constructed.

"2. Geologic mapping to determine stratigraphic and structural relationships will be conducted by the Department of Natural Resources, Geological Survey.

"3. Subsurface geologic studies will be conducted using available well logs and mapping completed in item 2 above.

"4. A surficial geologic map will be prepared rather early in the study so that relationships between the geology, hydrology, and surficial materials can be established.

"5. Compilation of hydrologic data using pertinent literature and available climatological, groundwater, and surfacewater control for the area will be used. At this time, approximately 10 to 15 of the wells inventoried in item 1 will be picked for periodic remeasurement of water levels.

"6a. Seepage runs will be conducted during the study at various intervals under different stream conditions. These will form a basis for detailed study of low-flow characteristics of the streams. Detailed work is necessary for determination of large stream-flow gains or losses. The work will consist of measuring groundwater levels, drilling shallow test holes in the valleys, geologic mapping, and subsurface dye tracing. This work has already started and will form a basis for other surfacewater needs added to the area. As stated above, the first phase of this part of the study is well underway. Data are being analyzed.

"6b. Dye tracing to help establish position of subsurface drainage divides and to outline catchment areas of springs has been started. At present, two dye traces have been run in the area and three more are in preparation. It is hoped that an almost continuous program of dye tracing can be instigated to help in determining the direction of water movement.

"7. Generalized aquifer parameters (how much water the aquifer will yield and what efficiency) will be established using surfacewater data coupled with pump test data. At the present time, the Survey has data from three controlled pump tests in the area, plus the results of short-term tests which were run when the wells were drilled on approximately 60% of the wells of which we have record. It is the intention of the Survey to collect more extensive pump-test data from approximately 30 shallow, domestic wells in the area, plus controlled pump tests on at least 10 more large-yield, deep wells.

"8. Existing wells and springs will be sampled. Some periodical sampling of selected wells for chemical analyses will be conducted to determine various geochemical parameters. This should aid in the location of recharge areas within the basin. At present, the Survey has in its files analyses from approximately 60 wells in the basin area and it is hoped that approximately 60 more samples can be gathered during the course of this study. It is felt that with this amount of data we should be able to adequately define the chemical nature of the ground water in this area.

"9. ERTS imagery will be used to define the distribution of forest and crop lands and to evaluate the relationship of runoff characteristics. Low level photography will be obtained if needed for more detailed information on land use and vegetation. Thermal imagery may be obtained in areas of anomalous stream flow conditions or in areas where some insight may be obtained on the relation of the stream flow conditions to geologic structure.

"Specific objectives of this study are:

a. To determine the low flow characteristics of the main stream and their tributaries. Any point where waste water or other effluent enters the stream must be evaluated and the stream must be classified as being losing, perennial, protected, etc.

b. To evaluate methods which will lead to better definition of losing streams and basins with deficient runoff. Determinations of definite recharge-discharge relationships are needed.

c. To determine the controls exerted on the hydrologic regime by natural processes present in all carbonate rock areas in Missouri.

d. To provide guidelines by which responsible officials can control development and manage the land-water resources wisely."

Thomas Hill Reservoir Area

Potable water of significant volume is available in the Thomas Hill area only from alluvium or glacial drift. Macon, Randolph and Howard Counties have inadequate drift materials for water production. The alluvium has not been evaluated, but it is believed to have capabilities ranging from 0 to 200 gallons per minute. The alluvial materials average about 40 feet in thickness (an unverified judgment) and the sands tend to be fine.

The test drilling program carried out by the State Geological Survey in the 1950's did not include Macon, Randolph or Howard Counties. However,

Chariton County was test drilled. The test drilling was carried out with 1-mile spacings in profiles 10 miles apart. Determinations of drift thicknesses and the nature of the materials provided an important and much needed basis for response to inquiries about water availability in a larger area of the state.

Water in bedrock formations is too saline for home and public water supplies, and for industrial or irrigation utilization. Consequently, most public and industrial water supplies have been developed by constructing impoundments.

Because groundwater supplies could not be successfully developed in much of this area, very few wells have been drilled and data are very limited. The area's potential for significant groundwater supplies is quite limited and test wells are so expensive to drill that the cost ratio for obtaining additional data would be prohibitive within current funding.

MINERAL RESOURCES

Lake of the Ozarks Area

Mineral resources in the Niangua-Grandglaize Drainage basin are principally nonmetals, although some metallic minerals are known to be present (fig. 2). Commodities produced on a continuing basis are limestone and sand and gravel. The value of reported mineral production for the five counties in the area in 1972 (the latest year data were available) was over $600,000. Since most of the annual values are concealed, Figure 3 is the trend line representing growth in the value of annual mineral production in counties in the study area.

NONMETALS

Sand and Gravel

Alluvial sand and gravel is an important resource in the area. Several streams have the potential for producing large amounts of gravel, although

LEGEND

METALS

LEAD

Inactive mine

ZINC

Inactive mine

IRON

IRON ORES (LIMONITE-HEMATITE) IN SEDIMENTARY ROCK

Maximum areal extent of brown iron ore (limonite) mining: 1815-1965

Maximum areal extent of red iron ore (hematite) mining: 1820-1956

NONMETALS

CLAY AND SHALE — REFRACTORY

Maximum areal extent of Southern Fireclay District
Cheltenham Formation (Pennsylvanian) in filled-sinks consists of flint, burley, and diaspore fire clays

Maximum areal extent of Northern and St. Louis Fireclay Districts.
Pennsylvanian sediments in districts contain bedded deposits of plastic and flint fire clays.

SAND AND GRAVEL

Sand and gravel pit
Production from alluvial deposits

STONE — LIMESTONE-DOLOMITE

Limestone quarry (crushed stone)

SANDSTONE

Sandstone quarry (dimension stone)

BARITE ("TIFF")

Maximum areal extent of mining in Central Barite District: 1868-1965
Circle deposits in district smaller and more abundant than those of residual type. Some contain lead or zinc.

Open pit mine and washer

TRANSPORTATION

RAILROADS

HIGHWAYS

95 — Interstate

58 — Federal

39 — State

RIVERS

A 9-foot navigation channel has been authorized by Congress for the Mississippi River to Minneapolis, and for the Missouri River from its mouth to Sioux City, Iowa

UTILITIES

ELECTRIC TRANSMISSION LINES

110,000 to 161,000 volts

44,000 to 69,000 volts

OIL AND GAS LINES

O — Oil

G — Gas

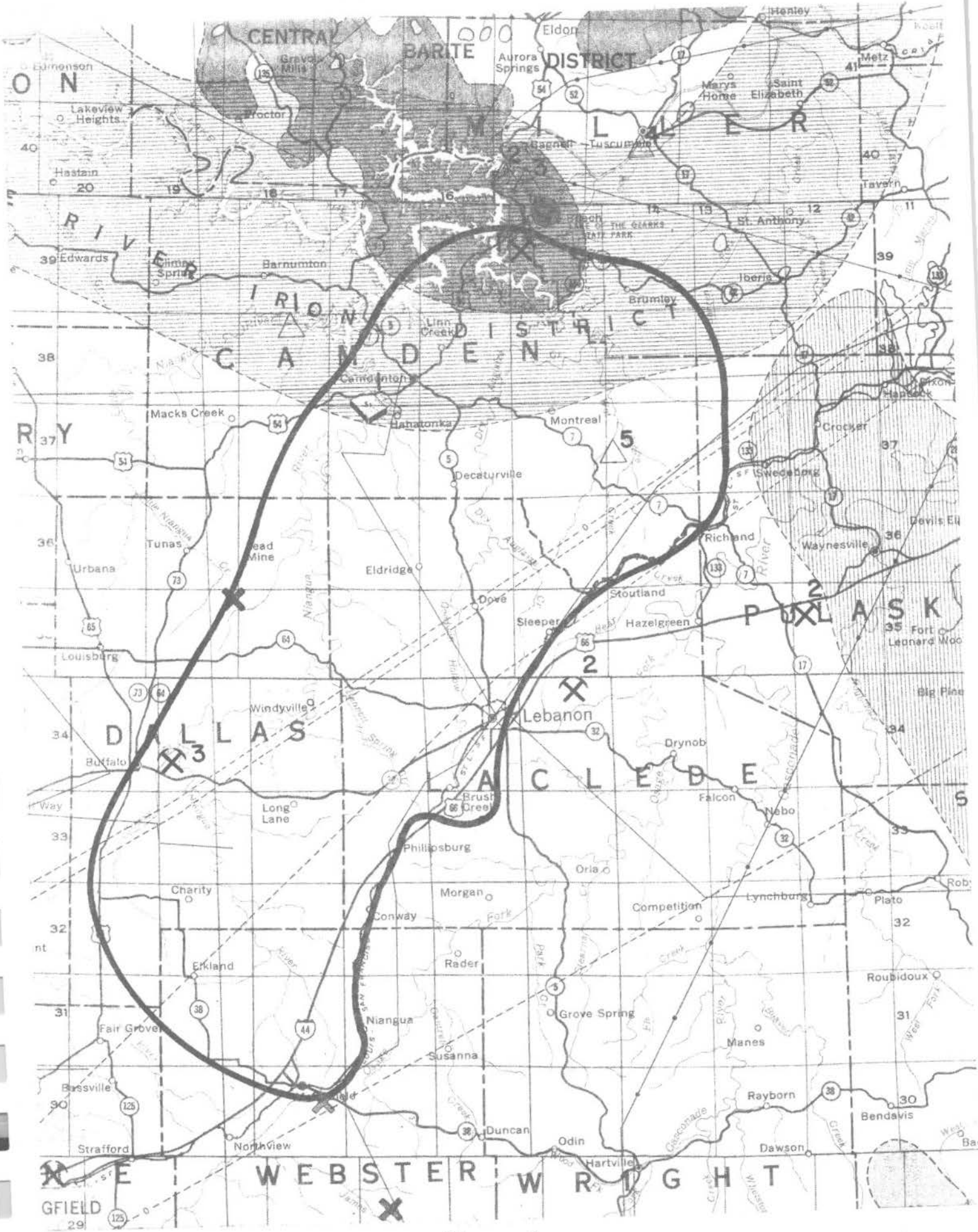

Figure 2

Map showing mineral resources in the Lake of the Ozarks area.

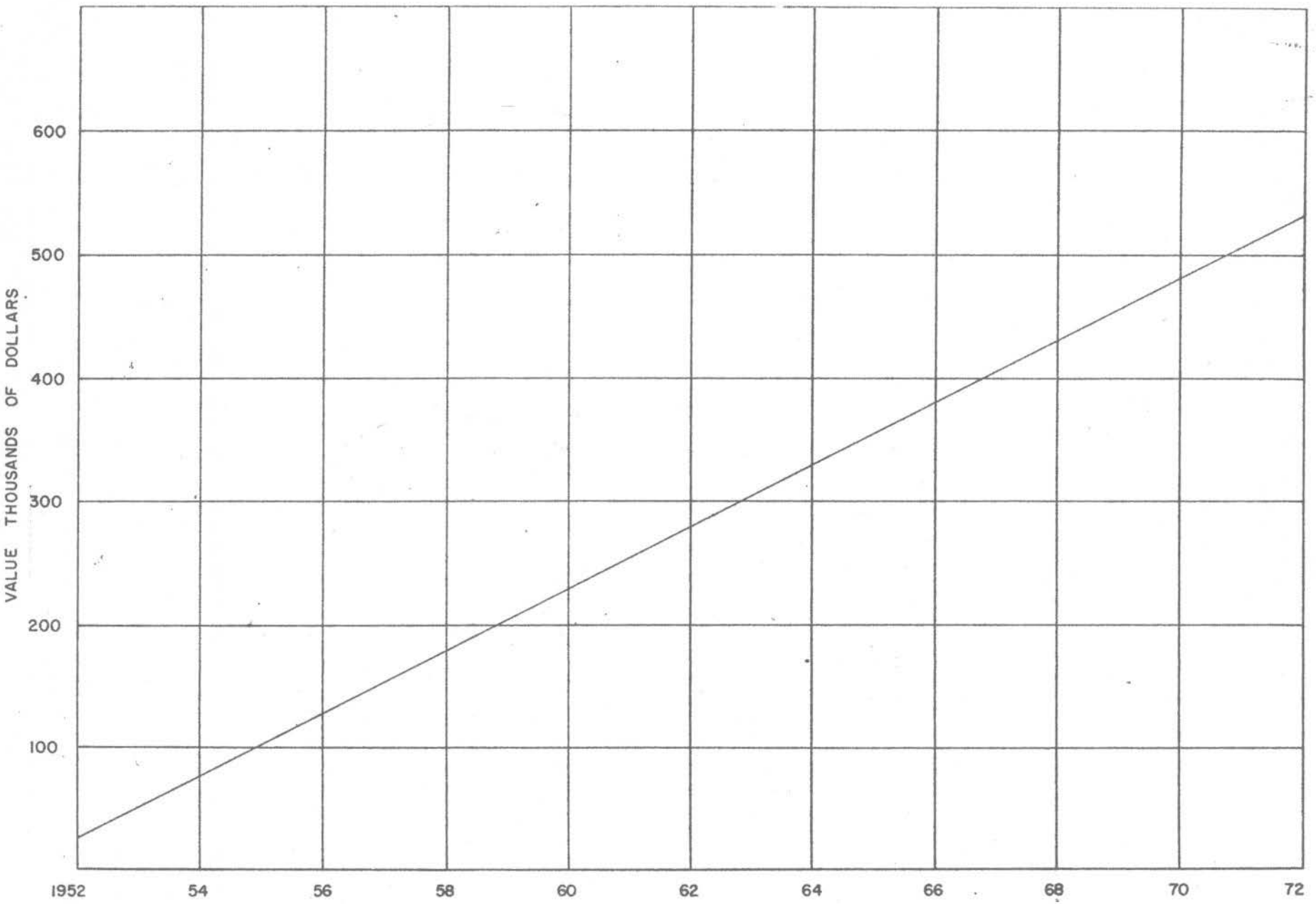

Figure 3
Value of annual mineral production in the Lake of the Ozarks area.

exploration will be required to locate the better quality deposits.

Chert sand and gravels derived from the surrounding cherty dolomites predominate, with quartz sand present in streams which drain areas of sandstone. Sizes of both sand and gravel are variable. Smaller streams contain considerable amounts of oversize gravel with clay and silt. The chert gravel ranges from smooth, dense, waxy brown types to porous particles. The sand fraction, generally present as an admixture in the gravel or occasionally as relatively clean bars, commonly consists of a mixture of quartz sand and sand-size chert fragments. The principal use of this material is as aggregate in ready-mix concrete and for paving, road metal and fill.

Sand and gravel represents a readily available, low cost source of construction aggregate for the area. Although resources are large, the effect of environmental considerations on future resource availability is not known.

Stone

Crushed and broken stone (a reporting category of the U.S. Bureau of Mines) and dimension stone are produced in the Niangua-Grandglaize drainage basin. Production is commonly reported from every county except Webster. Rock types produced are dolomite and sandstone.

Carbonate rock units quarried are the Ordovician-age Jefferson City-Cotter and Gasconade dolomites. Most stone production is from the Jefferson City-Cotter formations which form bedrock over most of the area. This unit is composed principally of gray to tan colored, medium to finely crystalline, argillaceous, cherty dolomites. The upper portion of the Gasconade formation is a massive appearing, coarsely crystalline, relative low chert dolomite.

Crushed stone production is used in asphaltic concrete, bituminous surfacing, road metal and for aglime. None of the rock units in the area are considered suitable for portland cement concrete aggregate. Resources of stone

suitable for low type aggregate and aglime use are more than adequate for the area.

Sandstone is produced in Camden County for use as dimension stone. The unit being quarried is the Gunter Sandstone Member of the Gasconade Dolomite. While sufficient reserves of material are available for dimension stone use, it is not felt that adequate reserves of sandstone are present for industrial sand uses such as glass manufacturing and abrasives.

Barite

Production of barite has been minor in the pilot study area, particularly in recent years. Total production from the region has been about 40,000 tons, virtually all of which was from Camden and Miller Counties. The mines in this region were developed in the mineralized collapsed or filled-sink solution structures termed "circles". The small diameter and limited tonnage of most of these deposits discouraged attempts to mine them on a large scale. These deposits are not believed to have any great economic potential.

METALS

Iron Ore

Parts of Camden and Laclede Counties lie in the Osage River Brown Iron Ore district. These shallow iron deposits are currently unimportant because of their generally small sizes, low grades, and lack of uniformity in composition. The most recent production was 720 tons mined in Miller County during 1957.

Possibly the most interesting iron ore prospect in the region centers around the Orla magnetic anomaly southeast of Lebanon in Laclede County. This prominent anomaly has attracted attention for many years, and several 2,000-foot drill holes have been put down to test the Precambrian basement rocks for a possible deeply buried magnetic iron ore deposit. The St. Joseph Lead Company drilled the first test near the center of the high around 1957. In 1966-1967, three additional

holes were drilled by Mofero, Inc. on the northern end of the anomaly. Disseminated magnetite was present in some of the Precambrian sections. Another hole was drilled by the American Zinc Company, at the center of the high, during 1968, but no results have been announced. It is possible that a large body of iron-rich basic rocks of no economic interest is present and has produced this large magentic anomaly. However, since this has not been conclusively proved, it is likely that additional test drilling will be done in search of a large, high-grade iron ore deposit.

Lead-Zinc

Lead and zinc have been mined in the Niangua-Grandglaize drainage basin, but production has been small. Little mining has been done in recent years because of the small sizes and low grades of the deposits. Prospects of new mining of these near surface deposits are negligible. The best possibility for exploration would be at depth. Some lead-zinc mineralization is associated with barite in the circle deposits.

The Decaturville structure in Camden County deserves some mention as an exploration target. This structure is believed to be a meteorite impact crater or a cryptovolcanic structure. Lead-zinc mineralization is known to be present in the area, and several unsuccessful drilling programs have been carried on. There are no firm data to indicate an exploitable deposit.

Active Mineral Operations in the Lake of the Ozarks Area

Sand and Gravel

Dredging, Inc.
Route 2, Box 85
Camdenton, MO 65020

Al Elam Sand & Gravel (Lake Ozark Sand & Gravel)
Lake Ozarks, MO

Ozark Sand Co.
Route 3
Eldon, MO 65026

Osage Sand & Gravel
Tuscumbia, MO 65082

Nelson W. Owen Sand & Gravel Co.
Route 3
Lebanon, MO 65536

Stone Quarries

Osage Asphalt, Inc.
Box 70
Osage Beach, MO 65065

Rush Quarries, Inc.
Route 5
Lebanon, MO 65536

Morgan Materials, Inc.
Box 167
Buffalo, MO 65622

Dimension Sandstone

Ozark Stone Products, Inc.
Box 322
Camdenton, MO 65020

Mineral resources in the East and Middle Fork Chariton River drainage basin include nonmetals and mineral fuels. Major commodities are coal, stone and minor amounts of sand and gravel are produced, although there are no major permanent operations (fig. 4). The value of mineral production reported in 1972 for the five counties within the basin was over $9 million with most of this value being represented by coal mining.

NONMETALS

Clay and Shale

Clay and shale suitable for the manufacture of structural clay products are common in the basin. Shale units with some economic potential are in the Lagonda, Little Osage, Nowata, Lenapah, and Holdenville Formations. There is no production now, although during the late 1800's and early 1900's brick making represented a considerable industry in the Moberly area. Changing economic conditions led to the replacement of the local brickyard with larger operations that are better suited to fuel supplies and transportation.

Sand and Gravel

Only minor amounts of sand and gravel are produced from alluvial deposits along the Chariton River and dredging on the Missouri River.

Glacial drift, ranging from a few feet to as much as 200 feet thick blankets much of the area. Small pockets of sand and gravel, generally too small for economic exploitation, are present in the drift. Stream deposits consist principally of fine to medium sand and contain considerable amounts of silt. Gravel deposits are scarce; however, coarse sand and gravel are sometimes present at depth overlying bedrock in some of the stream valleys. Further study might supply additional information on this potential.

Sand and gravel production, chiefly sand, is used as fine aggregate in readymix concrete and asphalt mixes. Resources of sand from the Missouri River

LEGEND

MINERAL FUELS

COAL

Maximum areal extent of past mining
Areas of intensive mining

$\frac{141}{36} \times \frac{\text{Depth to coal in feet}}{\text{Thickness of coal in inches}}$

Names of Coal Beds

Mb - Mulberry	B - Bevier	Mn - Mineral
L - Lexington	W - Wheeler	T - Tebo
S - Summit	C - Croweburg	Wp - Weir Pittsburg
M - Mulky	F - Fleming	R - Rowe (oldest)

Coal mine (open pit and tipple)

NONMETALS

CLAY AND SHALE — REFRACTORY

Maximum areal extent of Southern Fireclay District
Cheltenham Formation (Pennsylvanian) in filled-sinks consists of flint, burley, and diaspore fire clays

SAND AND GRAVEL

Sand and gravel pit
Production from alluvial deposits

STONE — LIMESTONE-DOLOMITE

Limestone quarry (crushed stone)

SANDSTONE
Sandstone quarry (crushed stone)

TRANSPORTATION

RAILROADS

HIGHWAYS

Interstate (95)
Federal (58)
State (39)

RIVERS

A 9-foot navigation channel has been authorized by Congress for the Mississippi River to Minneapolis, and for the Missouri River from its mouth to Sioux City, Iowa

UTILITIES

ELECTRIC TRANSMISSION LINES

110,000 to 161,000 volts
44,000 to 69,000 volts

OIL AND GAS LINES

O Oil
G Gas

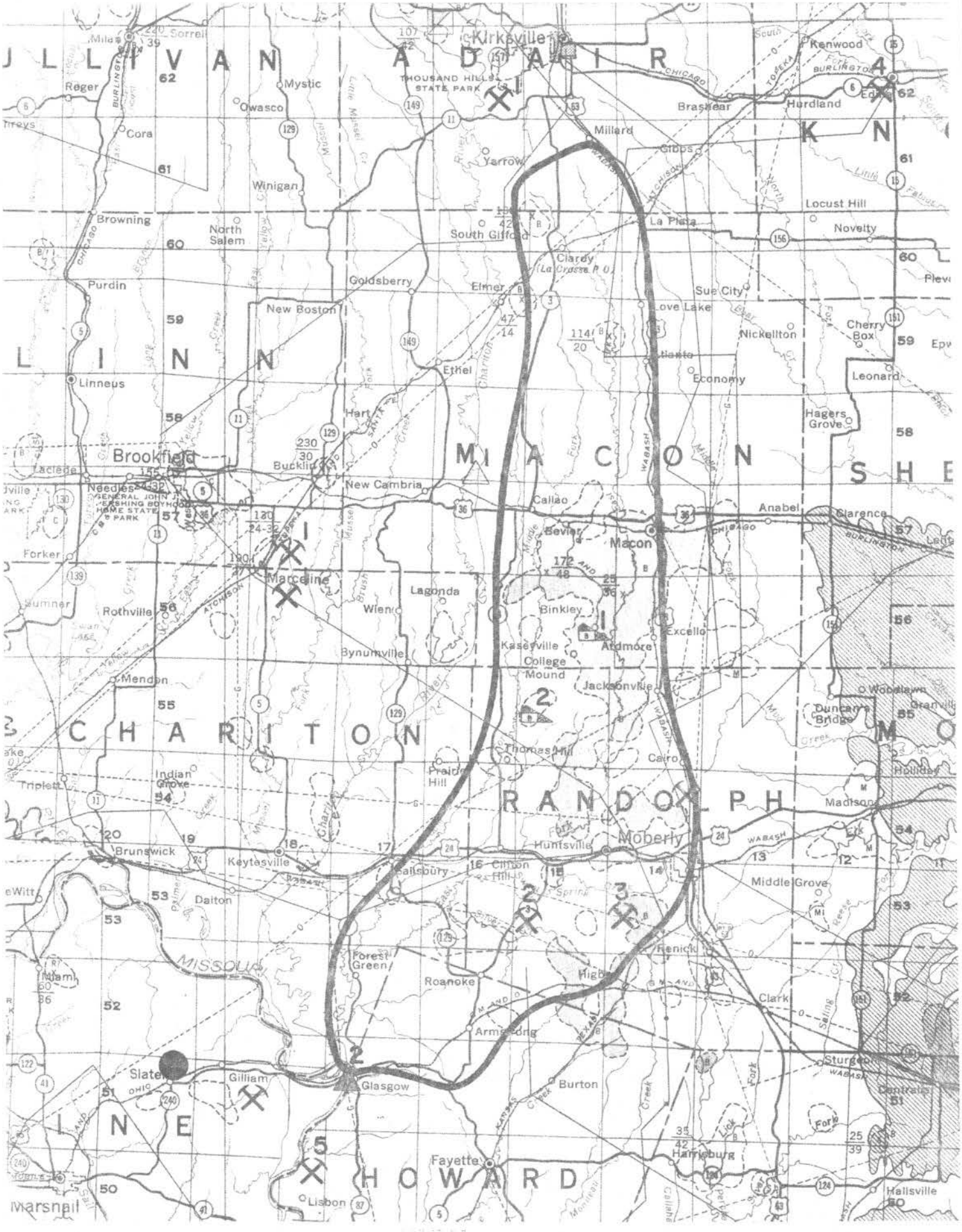

Figure 4

Map showing mineral resources in the Thomas Hill Reservoir area.

are practically inexhaustible. Sand supplies from the Chariton River and smaller streams in the area, while probably of lesser quality, are also nearly inexhaustible. Gravel deposits are rare however.

Stone

Crushed and broken stone is produced within the region, although it is limited. Much stone is transported into the basin from outside areas. Limestone is the only rock quarried.

The Pennsylvanian strata underlying the area consist of thin limestones, interbedded with thick sequences of shale and sandstone. In much of the area bedrock is overlain by as much as 200 feet of glacial drift. The two limestone units commonly quarried - the Higginsville and Myrick Station - range in thickness from 5 to 10 feet, thinning to the north in Macon County.

Crushed stone is used for aggregate in portland cement and asphaltic concrete, bituminous surfacing, road metal, and aglime. Stone resources are not large, although additional investigation might disclose other areas where supplies are near the surface. Higher quality stone from areas of Mississippian outcrop adjacent to the basin are commonly imported.

MINERAL FUELS

Coal

Most of the coal resources shown in table 3 for the four counties are located within the boundaries of the pilot area. These four counties contain a total coal resource base of more than 6 billion tons. The resource base includes all coal in beds more than 12 inches thick.

Nearly 2 billion tons of the coal resource base may be classed as a remaining mineable reserve. The mineable reserve includes coal occurring in deposits which can be mined with existing technology and under existing economic conditions. It should be pointed out, however, that economic factors are constantly changing and

that each coal deposit must be evaluated individually and its marketability judged in relationship to competitive deposits.

With existing mining technology, more than 600 million tons of the coal in the area is potentially strippable. Most of it is present in two seams, the Bevier and the Mulky (tbl. 4 indicates the quality of the coal). Both of these beds contain good stream coal, although the coal is high in both sulfur and ash.

Nearly 78 million tons of coal have been produced in the four counties to date, most of it in the pilot area (tbl. 5). Macon County leads with nearly 52 million tons, and Randolph follows with nearly 26 million tons. Although very little mining has been done in Howard and Chariton Counties, both contain substantial undeveloped coal reserves.

Four mines were active in the area in 1972 (tbl. 6). Production for the area in 1973 was 1,248,190 tons, most of it from Peabody Coal Company's Bee-Veer and Prairie Hill mines. These two large mines, in Macon and Randolph Counties respectively, supply coal to Associated Electric's Thomas Hill power plant. Two hundred and twenty-eight men were employed in coal mining the area in 1973.

The Thomas Hill Reservoir area possesses sufficient reserves to support an expanded coal-mining industry for many years. This could be in the form of increased electric power production or conversion of coal to other fuels such as gas, oil, or solvent-refined coal. Primary constraints on increased coal production are high sulfur content and environmental damage caused by strip mining. Improved technology may minimize both in the future.

Table 3

COAL RESOURCES AND REMAINING RESERVES

County	Total Original Resources (million tons)	Remaining Reserves (million tons)	Strippable Coal (million tons)
Chariton	1,138.94	277.86	139.40
Macon	2,339.10	574.38	67.99
Howard	1,031.00	245.14	202.13
Randolph	1,507.08	826.45	200.00
Totals	6,016.12	1,923.83	609.52

Table 4

AVERAGE ANALYSES - BEVIER AND MULKY COAL SEAMS

Coal	Btu/lb. as received	fixed % carbon	moisture %	ash %	sulfur %
Bevier	10,827	41.2	12.8	11.7	4.3
Mulky	11,450	39.6	10.6	10.4	4.7

Table 5

COAL PRODUCTION THROUGH 1973

County	Short Tons
Chariton	240,000
Macon	51,660,379
Howard	278,979
Randolph	25,607,207
Total	77,786,565

Table 6

COAL PRODUCTION BY MINE, 1973

Active Mines	County	Short Tons
Bee-Veer	Macon	719,684
Prairie Hill	Randolph	509,435
Frankhouser	Randolph	-----
Lowell Hargis	Howard	19,071
	Total	1,248,190

Active Mineral Operations in the
Thomas Hill Reservoir Area

Sand and Gravel

Wilkerson & O'Laughlin
address unknown

Glasgow Sand & Construction Co.
P.O. Box 115
Glasgow, MO 65254

Stone Quarries

Bailey Limestone Co.
1902 S. Baltimore
Kirksville, MO 63501

Green Quarries, Inc.
Hwy. U.S. 24 & 65
Carrollton, MO 64633

Quality Stone Co.
Route 1
Moberly, MO 65270

Knox County Stone, Inc.
c/o Mo. Gravel Co.
La Grange, MO 63448

Glasgow Quarries, Inc.
Route 2, Box 121
Glasgow, MO 65254

Coal Mines

Peabody Coal Co.
301 N. Memorial Drive
St. Louis, MO 63102

Bee Veer Mine
Box 233
Macon, MO 63552

Prairie Hill Mine
Box 150
Huntsville, MO 65254

Recommendations for Additional Study

The following are recommendations only and are not to be construed as commitments to a future study.

In the Lake of the Ozarks area, field investigations and more detailed analyses should be made of:

a. Limestone (dolomite) and sandstone suitabilities for crushed and broken and dimension uses, market and demand.

b. Sand and gravel sources and demand.

c. Resources in the southern part of the Central Barite district which lies in the northern part of the pilot study area.

Investigations recommended for the Thomas Hill area are of:

a. Coal resources, availability, and extraction potential.

b. Limestone resources, availability, potential uses, and demand.

c. Clay and shale resources that would be suitable for the manufacture of structural clay products.

d. Sand and gravel resources, provided surficial mapping (including subsurface data) is available.

Should there be follow-up studies in these areas, external funding would be required for part-time personnel to undertake any or all of the above projects.

ENGINEERING GEOLOGY

Engineering geology is the application of geologic principles to engineering practice to assure that the geologic factors affecting the location, design, construction, operation, and maintainance of engineering structures are recognized and adequately provided for. Emphasis is given to the problems of geology that affect construction on or in the earth. The study of surface physical features, soils, groundwater, bedrock, and past geologic history has important applications in engineering. Engineering geologic applications include evaluations of septic tank sites, sewage lagoon sites, effluent discharge points, solid waste disposal sites, water impoundment sites, hazardous terrain conditions, and others.

Data available for engineering geologic interpretations in the pilot areas are limited to that derived from a few small area studies, such as an investigation of landslides near Moberly and a field investigation of soil and rock materials for engineering geologic purposes along the Niangua Arm. The latter investigation is the only one in which land use interpretations could be made. Here, the characteristics of soil and rock materials that affect waste disposal were evaluated. This type of study could be used as a pattern for regional evaluation of the pilot areas.

Other existing information would require a considerable amount of reinterpretation for engineering geologic purposes. This includes county soil maps, geologic maps, data available from exploration (such as studies for proposed routes by the Missouri Highway Department) of field investigations by Survey geologists of proposed sites for lake sites. Additional data could be derived from existing aerial photographs and, to some degree, from data available from ERTS (LANDSAT).

The necessary steps in acquiring data for engineering geologic interpretation include obtaining basic geologic information, such as that shown on

1/62,500 maps of bedrock and surficial materials. Soil-mechanics properties should be determined for engineering purposes. Thickness of the soil cover is one of the primary factors in making a geologic evaluation of terrain. Studies to determine the time-of-travel for liquids are of great importance, particularly in the Lake of the Ozarks area where carbonate bedrock is widespread. Lastly, the characteristics of watersheds relative to their suitability for waste disposal must be considered. This may involve dye tracing studies to determine the rate of passage of surface water into groundwater aquifers and the direction of this flow.

The mapping of engineering geologic units would be on maps having a scale of 1/62,500 or 1/24,000. Final map scales would depend upon the needs of the user. The types of engineering geologic units designated in the study depend upon major engineering properties of soil and bedrock and their relationships as evaluated by the engineering geologist.

Assuming that maps and text illustrating the distribution of properties of bedrock and surficial materials were available, one more year would be required for completion of engineering geologic studies for the two pilot areas. An additional 1/3 man-year would be needed for necessary laboratory analysis (this does not include time for final map preparation).

VII. DATA ENCODING

Before any data can be placed in an electronic computer, it must be placed on appropriate forms using special codes that are designed for these data. The extracting of these data from normal sources and translating or converting them to these coded forms is called "data encoding". Before data can be coded, each format must be designed and established so that it can be utilized and understood by the computer. There is no magic system for data encoding. It is a relatively simple task to go from data files to data input cards to a keypunch and finally to a computer.

The encoding of data is time consuming and costly in the simplest of Electronic Data Processing systems but encoding parameters, like geocoding, are an integral part of the system design. Prerequisites are: a. a sound, practical classification of the various data, b. a complete data needs and sources inventory, c. determination of geocoding methods, and d. determination of graphic versus tabular retrieval.

It is anticipated that the Natural Resources Data System will ultimately require both graphic and tabular output. Graphic retrieval is by far the more costly of the two. The analysis of user requirements weighed against cost will be important factors in future decisions involving the two retrieval methods which have a direct effect on other requirements.

The major cost benefit of the pilot area concept at this stage is the relatively small data package that needs to be encoded for the test phase of the EDP system.

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Winslow, Arthur, 1894, Lead and zinc deposits: Mo. Geol. Survey, 1st ser., v. 6 & 7, 387 and 383 p., respt.

APPENDIX

One source of natural resources data is the Index to Remotely Sensed and Photographic Data available in Missouri. This index includes maps of areas covered plus tabulations of air photos, satellite imagery and other remotely sensed information available for each Planning Region in the State. It provides sources for these data as well as ordering information. Following is an outline of the index (to be published later this year) plus samples of the kinds of information it will contain.

(OUTLINE)

INDEX TO REMOTELY SENSED AND PHOTOGRAPHIC DATA AVAILABLE IN MISSOURI

I. Table of Contents

II. Introduction

III. Agency Descriptions

United States Department of Agriculture
Agricultural Stabilization and Conservation Service
Soil Conservation Service
Forest Service

Department of the Interior

United States Geological Survey
National Cartographic Information Center
Earth Resources Observation Systems
National Park Service

Department of Commerce

National Oceanic and Atmospheric Administration

General Services Administration

National Archives

National Aeronautics and Space Administration

Environmental Protection Agency

United States Army Corps of Engineers

Missouri State Highway Department

Missouri Department of Conservation

Department of Natural Resources

Division of Parks and Recreation
Division of Research and Technical Information

IV. Ordering

Introduction
United States Department of Agriculture - ASCS, SCS, FS
Department of the Interior - USGS, EROS, NCIC, Park Service
Department of Commerce - NOAA
General Services Administration - National Archives
U. S. Army Corps of Engineers
EPA
Missouri State Highway Department
Missouri Department of Conservation
Department of Natural Resources
    Division of Parks and Recreation
    Division of Research and Technical Information

V. Index Listing and Regional Maps

Introduction (Information on Base Maps, How to Read Regional Maps and the index listing)
State Map of Regional Planning Units

VI. Space Imagery

Description of LANDSAT (ERTS)
Description of Skylab
Description of NOAA
Ordering Space Imagery
    LANDSAT
    Skylab
    NOAA
LANDSAT Map
Skylab Maps

VII. Description of Private Imagery

VIII. Appendices

1. NASA Mission Data

2. Corps of Engineers Listing and District Map

3. EPA listing

4. Division of Research and Technical Information

5. Union Electric Listing

6. High Altitude USGS Coverage Map

7. Army Map Service/Air Force High Altitude Coverage Map

MID-MISSOURI REGION

COMPLETE COUNTY COVERAGE (see figure 5)

Audrain: ASCS - 1939, 1950, 1956, 1962, Aug. 4-6, 1968
Boone: ASCS - 1939, 1950, 1956, 1962, Aug. 5-21, 1968
USGS - 1948-1950 1:70000 Project 70-A
Callaway: ASCS - 1938, 1941, 1950, 1956, 1963, Sept. 19-26, 1969
SCS - Dec. 1974 1:48000
Cole: ASCS - 1937, 1941, 1953, 1958, 1965, Oct. 2, 1974
USGS - 1948-1950 1:70000 Project 70-A
M.J. Harden Associates 1974 1:6000 B&W
Cooper: ASCS - 1938, 1953, 1958, 1965, Nov. 9, 1973
USGS - 1948-1950 1:70000 Project 70-A
Howard: ASCS - 1939, 1953, 1958, 1965, Nov. 5-9, 1973
SCS - 1972 1:48000
USGS - 1948-1950 1:70000 Project 70-A
Moniteau: ASCS - 1937, 1941, 1953, 1958, 1965, Oct. 2, 1974
USGS - 1948-1950 1:70000 Project 70-A
Osage: ASCS - 1938, 1953, 1958, 1965, Oct. 2, 1974

PARTIAL COUNTY COVERAGE

SCS:

1935, Callaway Co., 1:15840 McCredie Creek Survey

USGS:

82) 1946 1:27000 BL
5) 1947 1:23600 FK
6) 1947 1:17000 EA
8) 1950 1:17000 IY
11) 1950 1:17000 ML
92) 1957 1:18000 GDL
86) 1958 1:22000 CFN
47) 1965 1:24000 VBBV
58) 1967 1:20000 VBPK
59) 1967 1:24000 VBPK
67) 1969 1:23000 VCDF
93) 1969 1:14400 VCDF
74) 1970 1:24000 VCJV
85) 1970 1:24000 VCMF
10) 1971 1:23000 VCPG
76) 1972 1:24000 SWFP
87) 1974 1:24000 VDKM

NASA:

Corn Blight 1971 

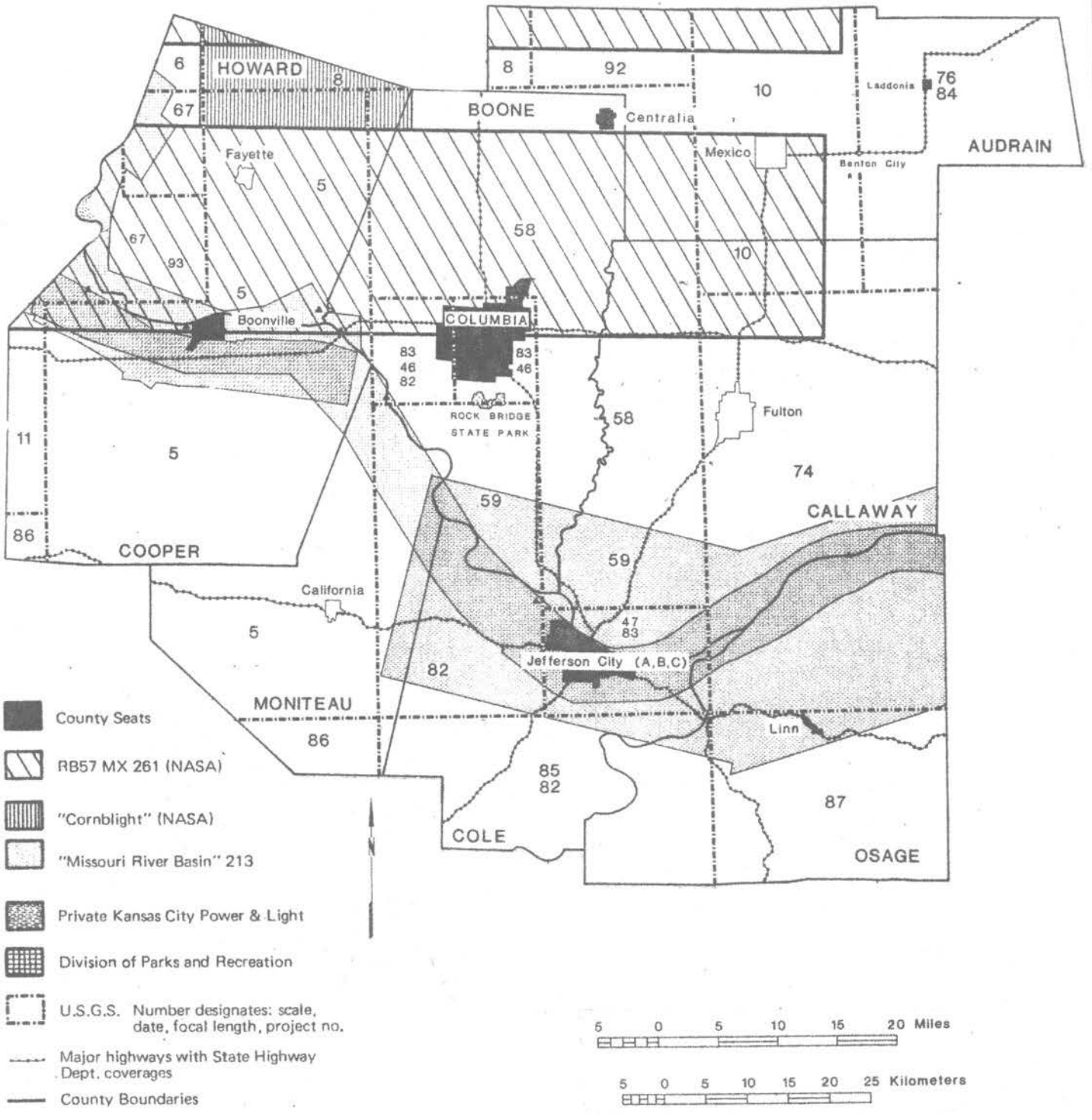

Figure 5
Map of Mid-Missouri Region included in Index to Remotely Sensed and Photographic Data Available in Missouri to show available data.

Mission 213 Missouri River Basin Sept. 11, 1972 

Mission 261 Kansas City/Moberly Nov. 28, 1973 

Flight 72-066 April 26, 1972 

Flight 72-083 June 6, 1972 

Flight 73-058 April 12, 1973 

NOAA: 

Sept. 7, 1961 1:32000 B&W
April 29, 1962 1:40000 B&W
June 10, 1964 1:24000 B&W/Color
May 18, 1967 1:30000 Color
Oct. 20, 1968 1:30000 B&W
April 25, 1972 1:30000 B&W
June 24, 1973 1:30000 B&W
Oct. 24, 1973 1:36000 B&W

MISSOURI STATE HIGHWAY DEPARTMENT:

DIVISION OF PARKS AND RECREATION 

Rock Bridge State Park
Feb. 13, 1968 9" x 9"
No date Medium

PRIVATE IMAGERY

CITIES & TOWNS: 

A) M. J. Harden - Kingdom City, Jefferson City, Boonville, Linn, Columbia, Centralia, Laddonia

B) Bucher and Willis - Jefferson City Mar. 1973 1:14400 B&W

Boonville Apr. 1974 1:12000 B&W

C) United Telephone Co. Jefferson City - March 1972 B&W

UNION ELECTRIC:

(See Appendix V)

UNITED TELEPHONE CO:

Area within 10 mile radius of Jefferson City 1:4800 B&W

KANSAS CITY POWER & LIGHT: 

March 1965

COMPLETE COUNTY COVERAGE (see figure 6)

Carroll: ASCS - 1939, 1953, 1947, 1963, 1967, Sept. 30 - Oct. 2, 1970
USGS - 1950 1:70000 Project 70-A
Chariton: ASCS - 1940, 1952, 1947, 1963, Sept. 27 - Oct. 28, 1970
USGS - 1950 1:70000 Project 70-A
Saline: ASCS - 1936, 1940, 1952, 1957, 1963, Sept. 29-30, 1970
USGS - 1950 1:70000 Project 70-A

PARTIAL COUNTY COVERAGE

SCS:

1936, 1937

USGS:

6) 1948 1:17000 EA
8) 1950 1:17000 IY
11) 1950 1:17000 ML
66) 1969 1:23000 VCDE
93) 1969 1:14000 VCDE
79) 1972 1:20000 VCXC

NASA:

Corn Blight 1971 

Mission 213 Missouri River Basin Sept. 11, 1972 

Mission 261 Kansas City/Moberly Nov. 28, 1973 

Flight 73-040 March 21, 1973 

Flight 73-058 April 12, 1973 

Flight 82 Westinghouse Radar 1965 

Flight 126 Westinghouse Radar 1966 

MISSOURI STATE HIGHWAY DEPARTMENT:

DIVISION OF PARKS AND RECREATION: 

Arrow Rock State Park
Nov. 28, 1972 9" x 9" Small

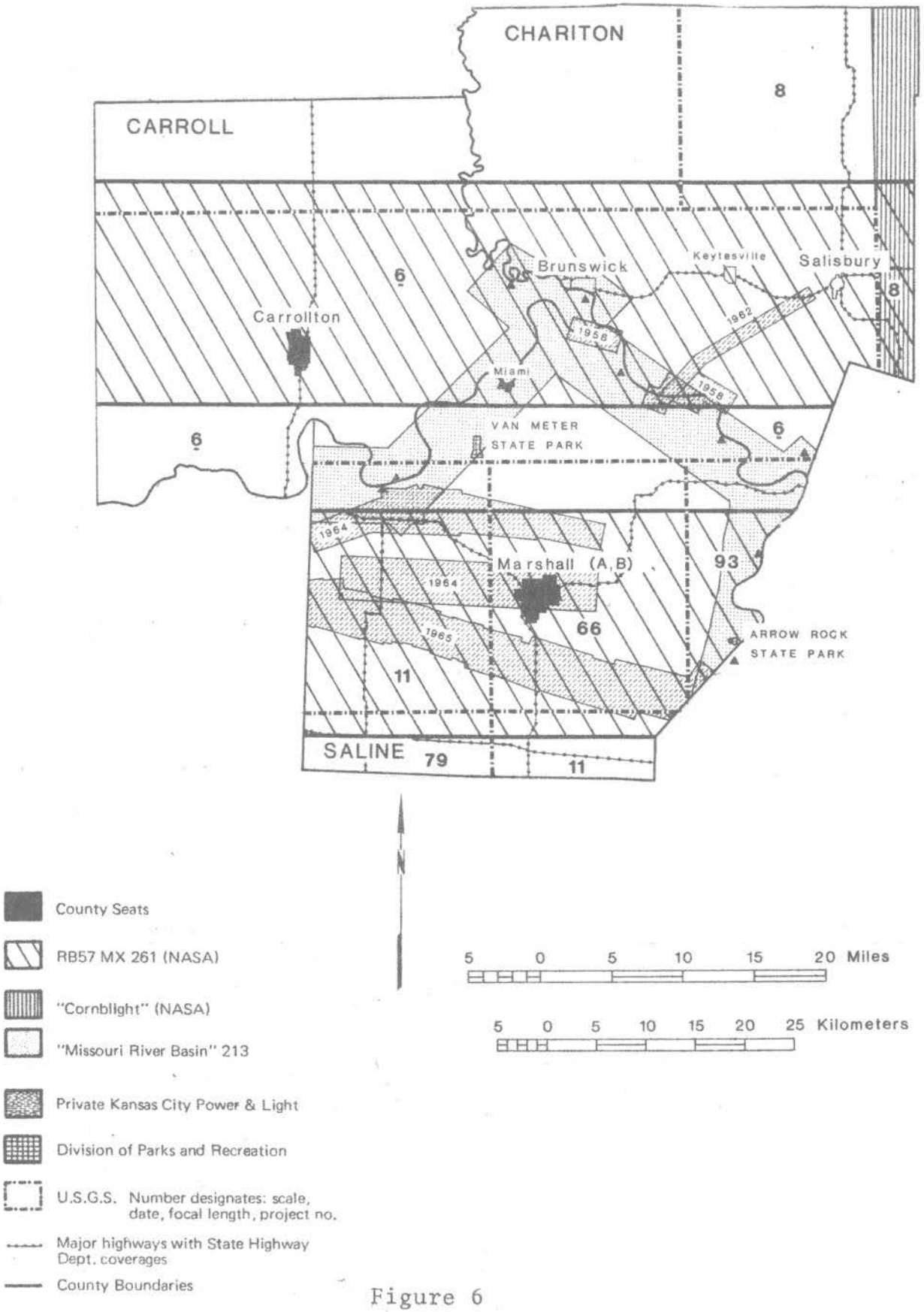

Figure 6

Map of Missouri Valley Region included in Index to Remotely Sensed and Photographic Data Available in Missouri to show available data.

Van Meter State Park
No date Medium

PRIVATE IMAGERY

CITIES & TOWNS: 

A) M. J. Harden - Carrollton
Miami
Marshall

B) Bucher and Willis - Marshall Feb. 1973 1:19200 & 1:36000 B&W

KANSAS CITY POWER & LIGHT: 

March 1958
March 1962
March 1964
March 1965

LAKE OF THE OZARKS REGION

COMPLETE COUNTY COVERAGE (see figure 7)

Camden: ASCS - 1938, 1953, 1960, 1967, July 3-4, 1968
Laclede: ASCS - 1939, 1955, 1964, Aug. 29 - Sept. 12, 1971
Miller: ASCS - 1938, 1955, 1961, Aug. 26-28, 1967
USGS - 1948-1950 1:70000 Project 70-A
Morgan: ASCS - 1938, 1953, 1958, Sept. 22 - Oct. 5, 1966
Pulaski: ASCS - 1938, 1955, 1964, Aug. 12-23, 1971

PARTIAL COUNTY COVERAGE

USGS:

82) 1946 1:27000 BL
5) 1947 1:24000 FK
12) 1952 1:24000 MU
15) 1958 1:24000 VRT
86) 1958 1:22000 CFN
99) 1958 1.24000 CHG
2) 1970 1:24000 VCME

NASA:

Flight 128 Westinghouse Radar 1966

NOAA:

June 23, 1971 1:30000 Color
June 26, 1974 1:30000 B&W

FOREST SERVICE:

Houston - Rolla District 1959 1:15840 Infrared
Houston - Rolla District 1967 1:15840 Infrared Project ERQ
Houston - Rolla District 1969 1:77000 B&W Project EVZ

MISSOURI STATE HIGHWAY DEPARTMENT:

DIVISION OF PARKS AND RECREATION:

Bennett Spring State Park
Sept. 16, 1961 Large Dec. 4, 1968 9" x 9"

Lake Ozark State Park
May 22, 1960 9" x 9"
Aug. 27, 1967 Large
Dec. 4, 1968 9" x 9" and Mosaic
No date Medium

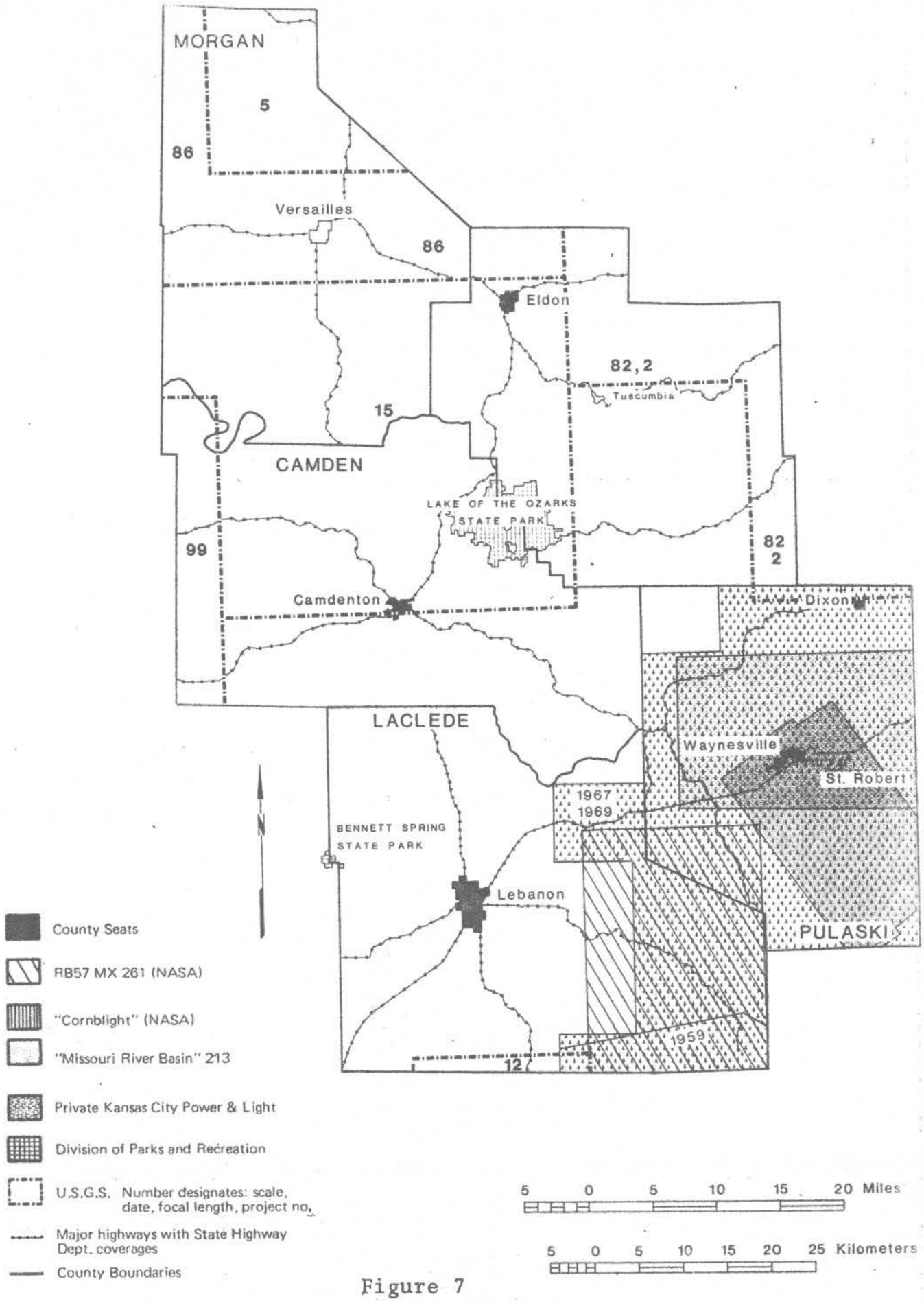

Figure 7

Map of Lake of the Ozarks Region included in Index to Remotely Sensed and Photographic Data Available in Missouri to show available data.

PRIVATE IMAGERY

CITIES & TOWNS:

A) M. J. Harden - Springfield, Monett, Clever, Republic, Kimberling City, Marshfield, Pierce City, Forsythe

B) Western Air Maps - Springfield: Dec. 21, 1966 1:12000 B&W
Dec. 13, 1970 1:12000 B&W

C) Bucher and Willis - Bolivar: July 1969 1:12000 B&W
Bolivar CBD: July 1969 1:3600 B&W
Bolivar: Feb. 1973 1:24000 B&W

Mark Hurd Aerial Survey

March 31, 1971 1:80,000 B&W Stereo Project CFL

MARK TWAIN REGION

COMPLETE COUNTY COVERAGE (see figure 8)

Lewis: ASCS - 1939, 1950, 1946, 1962, Aug. 20-28, 1968
USGS - 1956 1:60000 Project 55-AM-33
Macon: ASCS - 1939, 1950, 1956, 1963, Sept. 11-27, 1970
USGS - 1950 1:70000 Project 70-A
Marion: ASCS - 1939, 1950, 1956, 1962, Aug. 20-28, 1968
SCS - 1973 1:48000
USGS - 1956 1:60000 Project 55-AM-33
Monroe: ASCS - 1939, 1950, 1956, 1962, Aug. 20-22, 1968
Pike: ASCS - 1938, 1941, 1950, 1956, 1963, Aug. 22-Oct. 17, 1968
USGS - 1956 1:60000 Project 55-AM-33
Ralls: ASCS - 1939, 1950, 1956, 1963, Sept.28-Oct.22, 1970
SCS - 1973 1:48000
USGS - 1956 1:60000 Project 55-AM-33
Randolph: ASCS - 1939, 1950, 1956, 1962, Aug. 5-6, 1968
USGS - 1950 1:70000 Project 70-A
Shelby: ASCS - 1940, 1950, 1956, 1962, Aug. 20-22, 1968
USGS - 1950 1:70000 Project 70-A

PARTIAL COUNTY COVERAGE

SCS: 1936, Monroe Co. & Shelby Co.
USGS: 4) 1947 1:27000 DZ
8) 1950 1:17000 IY
92) 1957 1:18000 GDL
24) 1960 1:18000 VVY
20) 1961 1:18000 VADV
42) 1964 1:18000 VAVE
65) 1969 1:20000 VCCX
68) 1969 1:20000 VCDG
71) 1970 1:21000 SWDK
10) 1971 1:23000 VCPG
76) 1972 1:25000 SWFP
77) 1972 1:35000 SWFP
84) 1973 1:40000 VDDZ
89) 1974 1:24000 VDIJ
94) 1974 1:15000 VPIJ

NASA: Corn Blight 1971
Mission 261 Kansas City/Moberly Nov. 28, 1973
Flight 73-949 March 21, 1973
Flight 75-929A Feb. 26, 1975
Flight 82 Westinghouse Radar 1965
Flight 126 Westinghouse Radar 1966

NOAA: July 18, 1966 1:30000 B&W
June 28, 1974 1:30000 B&W

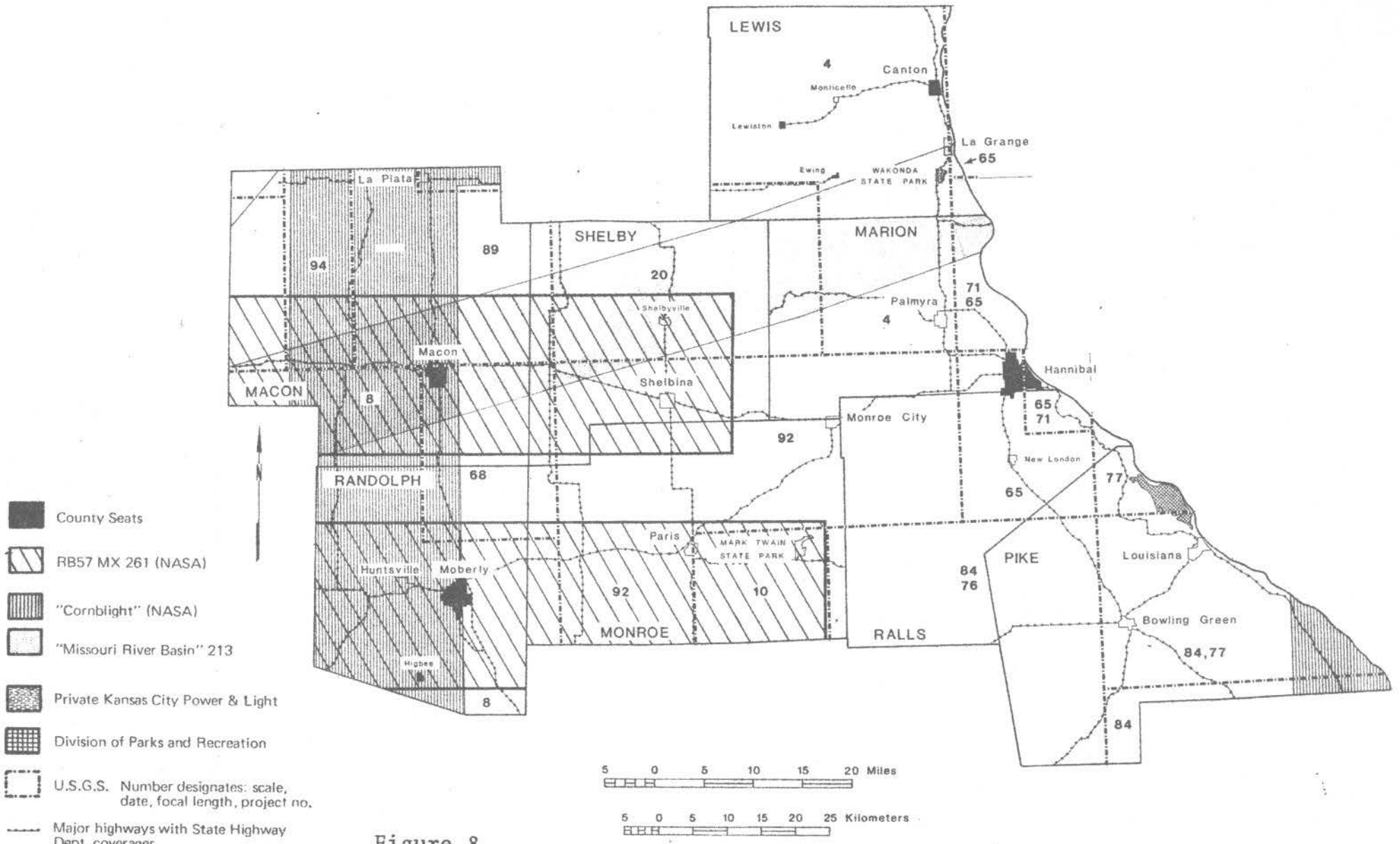

Figure 8

Map of the Mark Twain Region included in Index to Remotely Sensed and Photographic Data Available in Missouri to show available data.

MISSOURI STATE HIGHWAY DEPARTMENT:

Division of Parks and Recreation: Wakonda State Park - No date Medium
Mark Twain State Park - Aug. 28, 1962

MISSOURI DEPARTMENT OF CONSERVATION:

Ted Shanks Wildlife Area, March, 1974 1:4800 B&W

PRIVATE IMAGERY

Cities & Towns:

A) M. J. Harden -

Moberly	Stoutsville
Lewiston	Canton
Macon	Hannibal
Ewing	Higbee

COMPLETE COUNTY COVERAGE (see figure 9)

Barry: ASCS - 1938, 1955, 1961, Sept. 25-28, 1968
USGS - 1957 1:63000 Project 160-BJ
Christian: ASCS - 1938, 1941, 1955, 1961, Sept. 20-27, 1968
Dade: ASCS - 1938, 1953, 1960, May 23 - Oct. 9, 1967
Dallas: ASCS - 1938, 1955, 1961, Aug. 7 - Sept. 20, 1968
Greene: ASCS - 1938, 1953, 1960, Sept. 28 - Oct. 11, 1968
Lawrence: ASCS - 1939, 1953, 1960, July 10 - Oct. 9, 1967
Polk: ASCS - 1938, 1953, 1960, July 27 - Oct. 11, 1968
Stone: ASCS - 1955, 1961, Sept. 20-26, 1968
Taney: ASCS - 1955, 1961, July 4, 1968
USGS - 1957 1:63000 Project 160-BJ
Webster: ASCS - 1941, 1955, 1961, July 28 - Aug. 25, 1968

PARTIAL COUNTY COVERAGE

SCS:

1936 - Lawrence Co.
1937 - Barry, Christian, Douglas, Greene, Lawrence, Stone, Taney and Webster Counties

ASCS:

1939 - Lawrence Co.
1938 - Christian, Greene, Taney and Webster Counties

USGS:

7) 1949 1:27000 II
9) 1950 1:17000 IZ
12) 1952 1:24000 MU
97) 1958 1:20000 CHE
99) 1958 1:24000 CHG
18) 1959 1:17000 VSO
98) 1959 1:20000 CHE
104) 1959 1:18000 VXA
105) 1960 1:24000 VADX
50) 1965 1:24000 VBCB
61) 1968 1:21000 VBVY
62) 1968 1:21000 VBVZ
2) 1970 1:24000 VCME
72) 1970 1:20000 VCJV
81) 1973 1:24000 VDEO

March 8-9, 1972 - Multispectral Scanner/Thermal
1:7000 Predawn, Midday, Postsunset
1:36000 Midday

March 9, 1972 -
1:36000 Color, B&W (Red wave band), Color IR, B&W IR

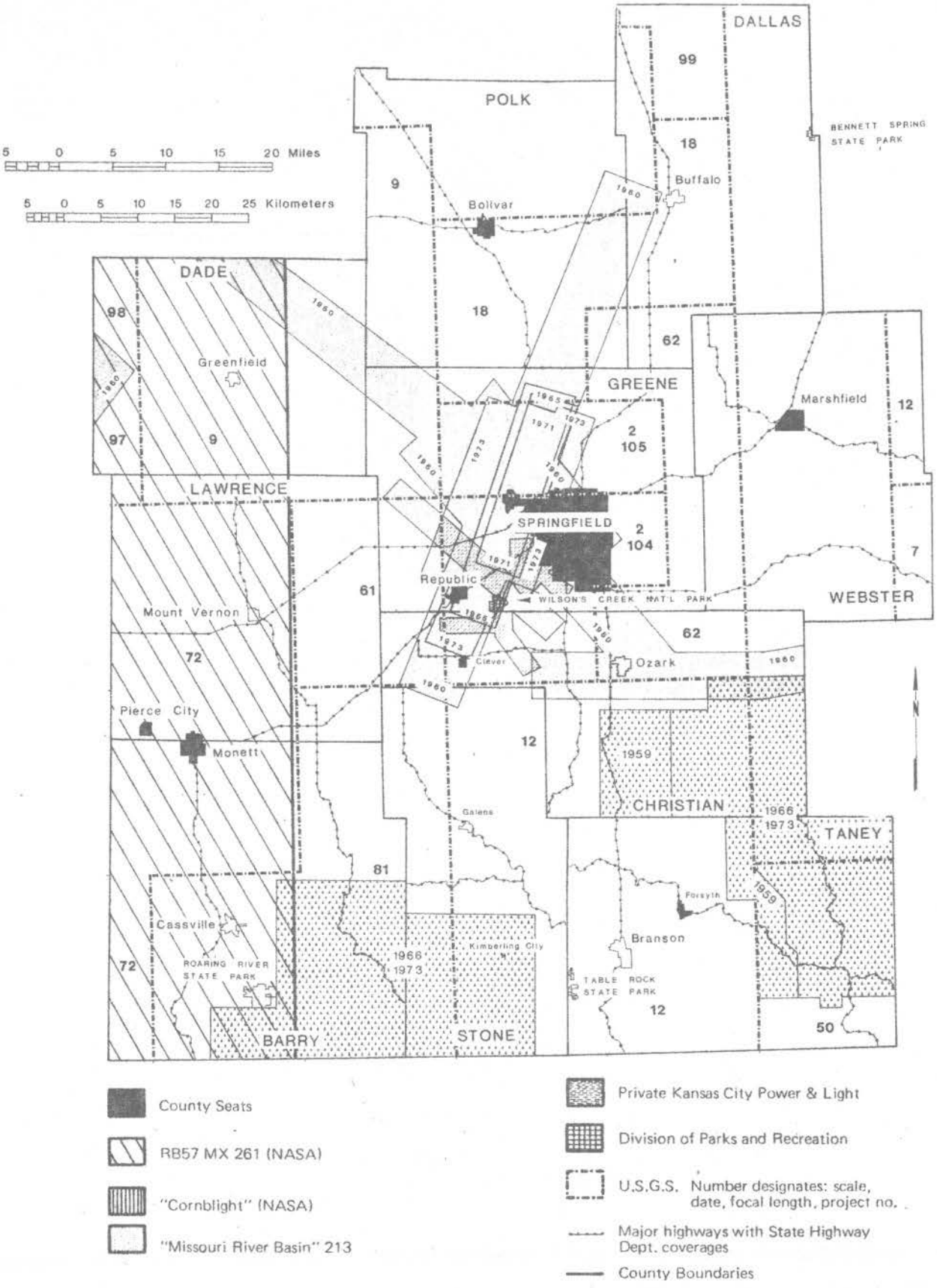

Figure 9

Map of the Lakes Country Region included in Index to Remotely Sensed and Photographic Data Available in Missouri to show available data.

June 20, 1973 - Multispectral Scanner/Thermal
1:7000 Predawn, Midday, Postsunset

June 21, 1973 - Multispectral Scanner/Thermal
1:36000 Midday

June 21, 1973 - Color, Color IR 70MM Format
1:7000 & 1:36000

NASA:

Flight 73-025 Feb. 23, 1973

NOAA:

June 29, 1960 1:33000 B&W
July 28, 1960 1:38000 B&W
July 12, 1965 1:30000 B&W
June 23, 1971 1:30000 B&W
June 25, 1973 1:30000 B&W

FOREST SERVICE:

Cassville District - 1966 1:15840 B&W Infrared Project EES
1973 1:72000 B&W Project 173
Ava District - 1959 1:15840 B&W Infrared
1966 1:15840 B&W Infrared
1973 1:72000 B&W Project 173

NATIONAL PARK SERVICE:

Wilson's Creek National Battlefield Oct. 1973
1:3000 B&W
1:6000 Color

MISSOURI STATE HIGHWAY DEPARTMENT:

DIVISION OF PARKS AND RECREATION:

Roaring River State Park
Dec. 2, 1968 9" x 9" and Mosaic
No date Medium

Bennett Spring State Park
Dec. 4, 1968 9" x 9"
Sept. 16, 1961 Large

Table Rock State Park
July 25, 1957 9" x 9"
Dec. 16, 1961 Medium

MISSOURI DEPARTMENT OF CONSERVATION:

Army Corp of Engineers Park Areas at
Table Rock Reservoir 1972 1:48000 B&W IR

PRIVATE IMAGERY

CITIES & TOWNS: 

A) M. J. Harden - Eldon
Camdenton
Waynesville
Lebanon
Dixon

B) Fairchild Aeromaps - Lebanon July 22, 1973 1:27600 B&W